

Lead Analysis of House Dust: A Method for the Detection of Another Source of Lead Exposure in Inner City Children*

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A method has been developed to test the hypothesis that lead-containing house dust is responsible for the elevated levels of lead in blood of inner city children. Dust analyses of smears from the floors, walls, and windowsills in low-income inner city dwellings have shown a median concentration of lead five times as high in suburban homes. It is suggested that lead-containing dust may be one of the most important environmental sources of increased lead exposure in this specific population group.

The association between childhood lead poisoning and long-term ingestion of peeling chips of lead-containing house paint is well recognized, and practically all of the reported cases of acute lead encephalopathy in early childhood can be retrospectively traced to this exposure source (1, 2). Prospective surveys conducted recently in many large cities in the United States have revealed that the entire population of inner city children of preschool age have mean blood levels of lead higher than those of suburban children in the same age group

(3, 4). The distribution of these increased blood lead levels suggests a more ubiquitous source of lead exposure than can be explained by the habit of pica (5, 6). Consequently, the ingestion of peeling paint chips has been questioned as the exclusive source responsible for the elevated exposures, and alternative hypotheses to the pica mechanism have been sought (3, 4). Lead-containing street dust has been suggested as a source of lead exposure, but no adequate data are available that can be directly related to this specific population (1). Interior house dust has been found to contain 0.1 to 0.2% of lead, and the theory has been offered that unintentional ingestion of household dust can exceed the daily permissible intake of lead in children (7).

A method has been developed to test the hypothesis that lead-containing house dust may be responsible for the increased lead exposures of inner city children; the technique was applied in a comparative study of

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children living in inner city houses and in suburban areas, reported earlier this year (4). The results demonstrated that lead-containing dust is present on inner city house hold surfaces and on children's hands in sufficient amounts to suggest a route of exposure that may be specifically applicable to preschool children.

Methods

A technique similar to those used to control surface contamination by radioactive materials (8) was selected in preference to the analyses of the content of lead in dust samples. This "smear and wipe procedure" more closely resembles what children might ingest than the simple concentrations of total lead in the particulate dust.

Moist, disposable paper towels, size 14 × 20 cm (44 in.²) impregnated with 20% denatured alcohol and 1:750 benzalkonium chloride were used to collect the specimens. Commercially available products, Wash'n Dri® from Canaan Products, Inc., Connecticut, or T-ette Premoistened Towelette® from Kenwood Products, Will Ross, Inc., Wisconsin, were used alternately throughout the study. Recovery tests were identical for both products, and other commercial towels may obviously be used as well. Test specimens were obtained by rubbing surfaces with a single opened towel, which was then placed in an individually labeled plastic bag and transferred to laboratory for analysis.

Hand Testing

The investigator washed his own hands first and then thoroughly rubbed each hand of the child on all surfaces and between the fingers. In studies where the distribution of lead contamination on the hands was tested, individual towels were used for every finger and for the palm. The investigator tried to keep the time for rubbing of the hand or finger surfaces approximately equal and standardized for all tests.

Household Surfaces

A template from 3/4-in. thick Lucite sheet

with an opening of 1 ft² was used to standardize the area of floor or wall surface tested. A single interior windowsill was tested, from a room where the child commonly played. Another specimen was collected from an area of uncarpeted floor in the same room. Attempts were made to keep the intensity and time of rubbing of every area as standard as possible, and to collect specimens free of paint flakes.

Analytical Procedure

In the laboratory, the paper towel was flattened on a clear surface, dried, rolled up and inserted into a test tube. A volume of 20 ml of 0.1N HCl analytical grade was added and the specimen eluted at room temperature for 10–15 hr. The eluates were decanted and 15-ml aliquots were taken for analysis. A 0.4 ml portion of 0.2% gelatin solution was added for suppression of polarographic maxima, and lead concentration determined polarographically on a Sargent Model XVI instrument. Polarographic waves were recorded from -0.24 to -0.69 V against saturated calomel electrode (SCE) (Fig. 1). Standard curve prepared from the stock solutions confirmed a straight-line relationship between lead concentrations and limiting current of polarographic waves (Fig. 2). The diffusion current of 0.03 μ A

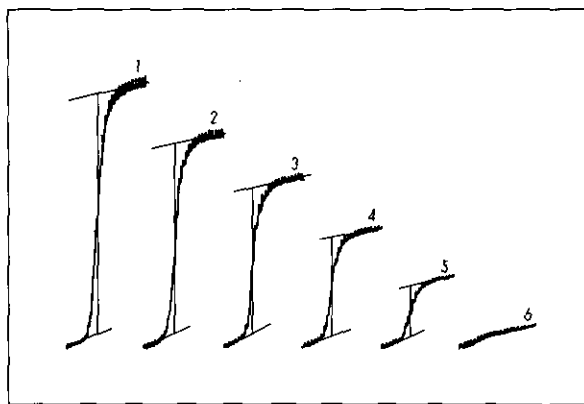


FIGURE 1. Polarograms of lead standards in 0.1N HCl. Waves were recorded from -0.24 to -0.69 V, sensitivity 0.006 μ A/mm, various lead concentrations: (1) 20 μ g/ml; (2) 16 μ g/ml; (3) 12 μ g/ml; (4) 8 μ g/ml; (5) 4 μ g/ml; (6) reagent blank.

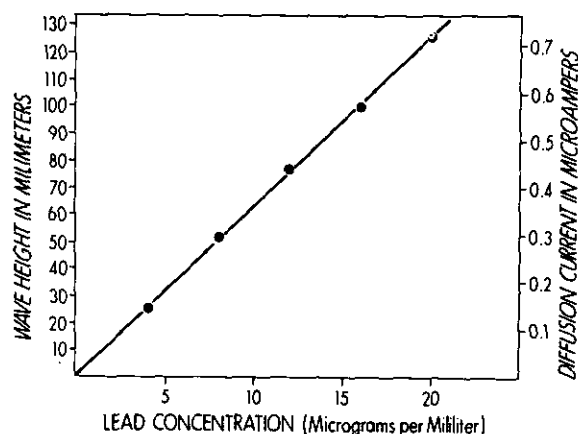


FIGURE 2. Standard curve of lead in 0.1N HCl eluates. The height of polarographic waves is given in millimeters and corresponding diffusion current.

corresponded to concentration of $1 \mu\text{g}$ lead/ml analyzed solution. Values reported in this paper were calculated as micrograms of lead obtained from the volume of 20 ml of 0.1N HCl eluate and represent on average a minimum 90% quantity of hydrochloric acid-soluble lead present on the towel.

Results

Negligible amounts of lead, well below the used analytical range of the method, were detected on unused towels. Recovery tests were performed by pipeting standard solution of two different concentrations of lead acetate on two commercial types of dry towels, and specimens were eluted by the routine procedure. Recovered amounts of lead acetate applied on the towel are presented in Table 1, and show that, on the average, approximately 90% of lead was recovered from both commercially available products. Preliminary tests performed on the investigator's hands and on the laboratory floor showed levels not higher than $20 \mu\text{g}$ of lead for both hands, or $40 \mu\text{g}/\text{ft}^2$ of laboratory floor. In contrast, after intentional contamination of hands by rubbing in a dust made from lead-containing paint chips, levels of up to $1000 \mu\text{g}$ lead per towel were obtained.

Table 2 presents the results of the test on efficacy of the standard rubbing procedure; the results are expressed as per cent of the cumulative contamination obtained after repetitive rubbing of children's hands and household floors. The data show that the standard smear represents on average only $2/3$ of total lead on the hand and approximately $3/4$ of the lead contamination of the floor. However, the low level of variance supports the conclusion that the amounts of lead obtained by this standard procedure are reliably reproduced, represent a prevailing part of the contamination and satisfactorily comply with the requirements of the test.

The reliability of the first smears has been further confirmed by repeated testing of the surfaces on the same floor or wall.

Table 3 shows that when sampling of the adjacent sites on the same wall or floor was done by standardized technique, the results of consecutive specimens did not differ by more than 20% in highly contaminated areas; somewhat larger differences on surfaces with low levels of contamination was noted.

Similarly, repeated sampling from the same dwelling done by four different investi-

Table 1. Recovery of soluble lead standard from towels.

	N	Lead found \pm S.D., μg	Lead recovered \pm S.D., %
Kenwood products			
200 μg Pb	6	180.9 ± 7.3	89.95 ± 3.65
100 μg Pb	6	88.7 ± 3.6	88.77 ± 3.57
Canaan products			
200 μg Pb	6	183.0 ± 5.7	91.5 ± 2.82
100 μg Pb	6	89.9 ± 4.9	89.9 ± 4.90

Table 2. Efficacy of the hand and floor smears expressed in percent of total contamination.

	N	Hands Total contamination, mean \pm S.E.M., %	N	Floor Total contamination, mean \pm S.E.M., %
First smear	6	68.7 ± 1.49	6	77.4 ± 1.62
Second smear	6	81.3 ± 1.89	6	22.6 ± 1.62

gators on different dates yields reasonably consistent readings (Table 4).

Table 5 shows the distribution of surface contamination on various parts of the children's hands, and documents the relatively even distribution of lead on the hand.

This method was used to study whether

Table 3. Variances in the floor sampling from the same floor.

	N	Lead, $\mu\text{g}/\text{ft}^2$ *	
		Range	Mean \pm S.E.M.
Floor A	5	256-302	264 \pm 15
Floor B	5	9.9-37.9	21.4 \pm 5

* Smears were sampled from five adjacent sites of the floor, each of 1 ft² size.

Table 4. Reproducibility of the smear testing.

Date	Investigator	Floor	Lead, μg per towel *	
			Window-sill	Child's hands
3/21	J.S.	308	304	258
7/17	E.T.	406	335	84
9/21	J.M.	256	207	115
9/22	J.V.	303	—	110

* Smears were sampled by four different investigators repeatedly from the same inner city home on various dates.

Table 5. Relative distribution of lead-containing dust on child's hands in percent of total amount sampled from one hand.

	Distribution of lead, %	
	9/21 (J.M.)	9/22 (J.V.)
Right hand		
Thumb	15.9	13.8
Index Finger	27.2	19.4
Middle Finger	11.3	13.9
Ring Finger	9.2	22.3
Small Finger	20.5	11.2
Palm	15.9	19.4
Total	100.0	100.0
Left hand		
Thumb	7.7	16.1
Index Finger	23.1	13.0
Middle Finger	11.4	22.6
Ring Finger	19.2	19.1
Small Finger	15.4	9.6
Palm	23.1	19.5
Total	100.0	100.0

significant differences in surface contamination can be found between predominantly old and deteriorating inner city houses and much newer houses in the suburbs (4). Two groups of houses and children were tested; the inner city households were those with children between 9 months and 6 years of age in which at least one child had previously been found to have a blood level of 40 μg lead/100 ml of blood or over. The suburban group consisted of children of the same age range living in more recently built homes.

A significant relationship was found between individual hand and house smears. The level of hand contamination clearly correlates with household levels (Fig. 3).

Figure 4 depicts the distribution of hand and household levels of lead contamination in the city and in suburbs. Highly significant differences were found between inner city and suburban homes for both hand and household contamination when medians of both groups and levels above and below these medians were compared (Table 6).

The range of the lead concentrations found in the floor smears from inner city old houses and houses constructed under the urban re-

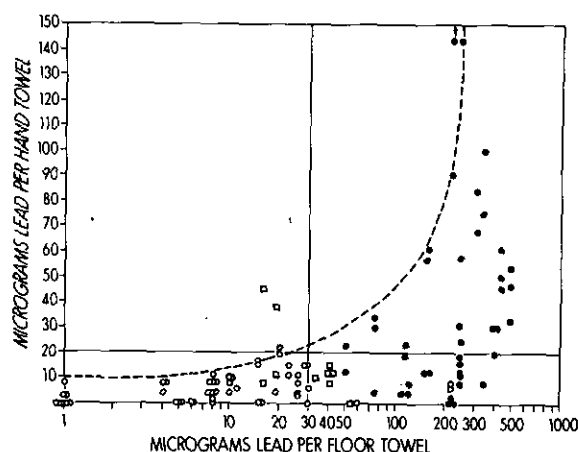


FIGURE 3. Correlation between household levels of lead-containing dust and hand contamination: (●) samples collected from 44 children living in predominantly old and dilapidating inner city houses; (□) from 10 children living in old but repainted inner city dwellings; (○) from 50 children living in suburbs.

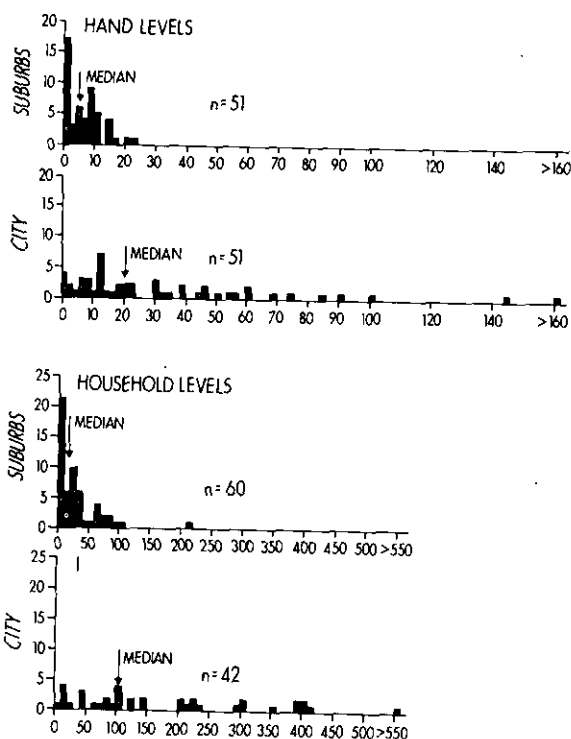


FIGURE 4. Distribution of hand and household levels obtained from 102 children living in the city and in suburbs. From Sayre et al. (4) Reprinted by permission.

newal programs in the same area are compared with lead concentrations found in suburban homes (Table 7).

Discussion

The fact that an increased lead exposure of preschool children may be associated with environmental factors other than ingestion

Table 6. Combined inner city and suburban hand vs. household smears ($N = 96$ children).^a

Hand level, μg lead per towel	Number of various household levels	
	<30 μg Pb/towel	>30 μg Pb/towel
<10	25	24
>10	5	42

^a Data of Sayre, et al. (4). $N = 96$ children. $\chi^2 = 16.4$; $df = 1$; $P < 0.001$. Each child was assigned the higher value of his two household specimens (floor or windowsill).

Table 7. Range of found floor contamination in inner city old and new houses and in suburbs.

Lead, μg per floor smear	
Inner city	
Old housing (18)	33-486
New housing (18)	2-24
Suburban houses (26)	0-60

of peeling paint or plaster was mentioned as early as 1964 (9), and Chisolm and Harrison emphasized the possibility of a multiple environmental source involved in the pathogenesis of childhood lead poisoning (10). Kehoe reported levels of lead in the urban dust higher than in the soil of agricultural rural areas (11). Recently, both inhalation or ingestion of street dust presumably from automotive emissions have been considered as additional sources of lead ingestion (1).

The average lead concentrations found in the dustfall samples collected in the study of 77 midwestern cities in 1970 (12) did not reveal differences between various sections of the cities studied; lead levels in the dustfall samples from commercial areas were only slightly higher than those from the industrial and residential areas. Though this result cannot explain the differences in lead exposure between inner city and suburban children of the same metropolitan area (1, 2, 4), repetitive swallowing of lead-containing street dust was mentioned as a plausible cause for higher blood lead levels reported in urban children with pica (1). Concentrations of lead higher than 0.1 to 0.2% of dry weight have been also reported in random sampling of the interior house dust in Boston, and ingestion of household dust has been suggested as a source of increased exposure in childhood (7).

A similar working hypothesis initiated the development of the method presented in this paper and studies were designed to explore whether or not sufficient quantities of lead can be found in city house dust to explain the differences in blood lead levels observed among city and suburban children. Contamination of children's hands by repeated contact with floor or windowsills and subsequent repetitive ingestion of deposited

lead by frequent hand-to-mouth activities, typical for preschool children, were considered to be the underlying mechanisms responsible for the increased intake of lead (4).

The data obtained are in agreement with the working hypothesis, in that they confirm the presence of median lead concentrations approximately five times as high on the interiors of inner city houses as those found in suburban homes. Moreover, the results indicate that lead can be easily removed from sites within the reach of young children. This was supported by the positive correlation found between the amounts of lead on household surfaces and on hands of children living in those houses.

The theory implies that the lead on children's hands is then ingested and absorbed in sufficient quantities to result in an elevated blood level. At present, there is no direct evidence to support this idea. However, if only 50% of the average hand contamination is transferred into the mouth and swallowed several times per day, the daily permissible intake may be easily exceeded, especially since the intestinal lead absorption has been found much higher at young ages than in adults (13, 14).

Sayre et al. (4) suggested that the proposed hand-to-mouth transfer of lead has several theoretical points in its favor. It can easily explain the general character of changes in the distribution of blood level for the entire population rather than isolated elevation in a selected group of children. Furthermore, it is consistent with the fact that the blood levels do not fall significantly until 5 years of age, and hand-to-mouth activities do persist in the majority of children until that time.

Certainly our data do not confirm that the contamination of hands by lead-containing house dust is the exclusive source of the undue exposure of inner city children. Many other environmental factors such as increased daily intake from lead-containing canned food or evaporated milk, iron deficiency (15), or increased rates of intestinal absorption of lead (13, 14) must be con-

sidered. The fact that the increased exposure is characteristic only for the age group between 1 and 5 years makes the other general sources such as air and water improbable. On the other hand, the ubiquitous presence of lead and the ease of repetitive contamination of hands present the assumed hand-to-mouth route of exposure as one of the most important environmental mechanisms involved in the genesis of moderately increased exposure in this high-risk population group.

Our results do not allow the identification of the source of lead in contaminated households. The question of whether this contamination originates from the inside of the house or is brought in from the polluted external environment cannot be answered at the present time. The fact that similar levels of contamination have not been found in newer housing but located in the same external environment, suggests, however, that the lead originates from within the old houses. Surprisingly high levels of contamination of uncarpeted and worn surfaces of old wooden floors or floors covered with broken linoleum have been found in homes with freshly painted walls but with deeper layers of leaded paint. This suggests that the scraped lead paint may remain accumulated on the unsealable floor surface long after the walls have been remodeled.

On the other hand, levels of lead found in the street dust in the nearest vicinity of old deteriorating houses were also high (up to 2 mg lead/g dust) and correlated well with high concentrations of lead observed in smears from deteriorating paint on the exterior walls and windowsills (up to 23 mg lead per outer wall smear). Since the outside dust may be easily carried into the homes on the soles of shoes of those entering, this outside source must be considered as well.

The data obtained in our study do not distinguish between inside and outside origin of the lead found within the homes. However, they undoubtedly indicate a closer association of high levels of lead in the house-dust with deteriorating housing conditions of the inner city dwellings than with air-

borne lead from automotive emissions. Since a direct relationship has also been found between contaminated households and levels on the children's hands the possibility exists that lead-containing housedust may be one of the missing links to explain the increased lead exposure of children living in the inner city area.

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